The Biomass Controversy

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The Problem

There is considerable ongoing discussion about whether we should burn biomass. The proponents for banning this practice contend that burning biomass evolves more carbon dioxide than burning fossil fuel in order to produce the same amount of energy. They are right, but they are only looking at one side of the issue. One most look at the big picture and consider not only the CO_2 evolved on burning but also that which is consumed in the formation of the fuel.

A Comparison Of Fossil Fuel and Biofuel

Both kinds of fuel obtain their energy from the sun which enables photosynthesis to occur by reacting CO_2 with water to produce carbohydrates and other carbon containing compounds along with oxygen. Hence CO_2 is removed from the atmosphere in this process. The difference entails what happens to these organic compounds.

For fossil fuel, they are converted through geological processes involving heat and pressure into coal, oil, and natural gas. This is a very slow process, taking thousands of years or more. These products are then extracted and eventually used as fuel for electric power generation, heating, and transportation fuel. This involves burning, where they react with the oxygen of the air to give back CO_2 and water. The amount of CO_2 yielded will equal that absorbed during the formation of the biofuel. Hence, the process can be considered "CO_2 neutral". It must be realized, however, that whether it is really neutral is dependent upon the time scale. For it to be so, the burning should occur during a similar time period to that involved in the formation and conversion of the fuel. This is usually not the case, since the burning usually occurs in a very short period of time as compared with the very long times required for the fuel to form.

Thus, for the usual times being considered, the process is not really neutral but rather "CO_2 positive". We are adding to the CO_2 content of the atmosphere, just as spending the money in the bank placed there by our ancestors cannot be regarded as a positive contribution to our economy.

With biofuel, the situation is different in that the step of conversion of the biomass into fossil fuel is eliminated, so the time during which the CO_2 is absorbed is just that for the photosynthesis necessary to form it. This time depends on the kind of biomass being used and ranges from a few months for some agricultural crops and grasses to many years for trees. In any case, the time scale for being "CO_2 neutral" is much shorter than for fossil fuel.

Is Biofuel Carbon Neutral?

It follows that whether or not burning biomass is CO_2 neutral or not depends upon the practices of the users. The fear is that those interested in quick profits from energy generation and sales will burn the biomass at a faster rate than required for its replacement by photosynthesis, and will lead to the undesirable depletion of the resource. This is environmentally unsustainable and should not be accepted practice. One should insist on "sustainable harvesting" whereby the biomass is harvested at a rate such that it can be replaced by additional photosynthesis and not lead to a depletion of the biomass resource. Doing such is more expensive since selection. in harvesting is necessary and its collection must be made from a much greater area than otherwise. This involves the cost of transporting the biomass, often rather bulky. Furthermore, the areas for collecting for various biofuel facilities may overlap, leading to their competing for the same resource. With this limitation, many believe that in the present economy, this practice cannot be carried out profitably, so if it is required, investors are not likely to participate.

Sustainable Harvesting

For sustainability, it is essential that the requirement for sustainable harvesting be enforced. It is a question of whether regulators have the ability and will to do this. Investors would most certainly press to relax this requirement, so the success depends upon whether governmental groups have the strength to resist such pressures.

Pollution

Another factor to consider is that of pollution. Biomass containing many organic compounds, some of which will be volatilized and/or converted to others which may be toxic and these may be evolved during burning. The amount of these can be affected by burning conditions involving air supply and temperature, such that their oxidation leads to forming simpler molecules such as CO_2 which, albeit a “greenhouse gas”, is not toxic. Other evolved product in the vapor can be removed by “scrubbing” the fumes where these undesirable species are absorbed by a substrate which then may be disposed of in a manner such as not to contaminate the environment.

There is also the concern about evolving particulate matter, small particles carried aloft in the evolved vapors which may present a heath hazard. There is the possibility that in some cases, there may be more of such arising from biomass burning than from fossil fuel. In any case, the technology exists for removing the particulates from the fumes, and it should be insisted that it be employed.

Another concern is that certain kinds of biofuel may contain material like construction waste and lumber that has been treated with preservatives. These can give rise to contaminants, many involving heavy metals, which may end up in the fumes or the ash. It follows that such source material should not be used, although its use has been permitted in some of the plans.

All of these means of preventing pollution add to the cost and decrease the favorability of using biomass as fuel. It should be realized that some fossil fuels, such as some coals, also contribute contaminants such as mercury, so that comparisons arte necessary. Included,. In comparing the economy of use of biomass and fossil fuels, it is essential that all of these considerations be made, and that the cost of assuring that processes are pollution free be included.

A "Cradle-To-Grave" Cost Analysis

It follows that in deciding whether large biofuel facilities such as those proposed for Massachusetts are desirable, a realistic cost and environmental impact analysis should be made. Many of the opponents of these believe that if subjected to the above requirements, the facilities would not represent a sensible approach. It may be so at some time in the future when fossil fuel costs grow or when penalties are applied for their release of CO_2, but it is questionable whether this is so now.

What About Coal?

A question is that if we do not proceed along the path of building large biofuel facilities, what then? People will still want energy so alternatives must be considered. There have been a number of proposals for meeting these needs by building more coal-powered plants. Such is encouraged by the coal mining industry which has available supplies of coal that are probable sufficient to last for at least several decades. However, most climatologists strongly oppose doing this since they believe that the increased global warming arising from the increased CO_2 evolution would be a climate disaster.

A reaction of coal producers is to advocate what they refer to as "clean coal", but many have questioned whether this is possible. The need to enforce thorough scrubbing of effluents is realized, and this should be required, although such is certain to cause some increase in power costs. However scrubbing will not serve the need of dealing with the increased CO_2 output and means must be considered to deal with it.

What To Do With the Carbon Dioxide

There are several options for this:

1. Absorb the CO_2 by some material or chemically react it to store it in a stable form.
2. Absorb it using “artificial trees”.
3. Dispose of it in the sea.
4. Store it in underground cavities.
5. Convert it into biomass through photosynthesis by trees and vegetation.

There does not appear to be viable technology at present for carrying out (1). There are studies of the use of porous materials or nanotubes, but present views are that the cost would be excessive. The same is true of (2) where the use of real trees is probably more economically risky. In both cases, one has not disposed of the CO_2 and one still must face the problem of disposing of the matrix containing it.

Approach (3) is currently occurring through natural processes or by pumping the CO_2 into the sea. It reacts with the water to form carbonic acid, increasing the acidity of the seawater. Natural absorption has probably reached saturation and the acidification of the water is believed to adversely affect marine life and cause damage such as the bleaching of coral. Alternatively, there is the approach of pumping it deeply in the sea where the pressure causes it to liquefy and its density is sufficiently great so that it would remain in the sea floor as a liquid. Three problems with this are:

1. The stability of these undersea pools of liquid CO_2 is uncertain. It might be dispersed through underwater currents or undersea geological activity.
2. It would take pressure to force the CO_2 to deep in the sea. The pressurization requires energy.
3. The approach would be more difficult for coal plants not close to the sea. The piping of it to bring it there could be costly.

The bottom line for this is that it seems unlikely that the technology and economics will make this approach viable in the near future.

Approach (4) is currently being tested, and it is a possibility that should be considered. However, there are some problems with this also:

1. Suitable underground cavities only exist in particular locations. It could be costly to pipe the CO_2 to suitable locations.
2. It is uncertain whether the capacity of these is adequate to hold the amount of CO_2 produced by the proposed coal plants.
3. There are uncertainties about the stability of this underground storage. Many feel that our knowledge of geology is not great enough to be confident that this CO_2 will remain there for long periods of time. There is some evidence that it presence may lead to disturbances such as earthquakes.

One variation of this approach is to use partially depleted oil wells. Pumping CO_2 into these has the advantage of aiding additional oil recovery, helping with the cost.

Sequestering By Photosynthesis

Approach (5) is time-tested and has been demonstrated to be viable provided sufficient area for growth is available. It has worked for many years, but its effectiveness has decreased as forest areas are cleared to allow for urbanization, fuel, and farming. Much of Europe was initially forested, but not so now. Planting trees to reverse this trend helps, but most feel that not enough of this can be realistically done to absorb the large amounts of CO_2 that would be produced. Biological and genetic studies aimed at improving the rather low efficiency of photosynthesis are desirable, but I suspect these will not happen quickly. A "blue sky" effort would be to have "artificial photosynthesis" whereby CO_2 and water are combined, with the aid of light energy, to form fuel producing organic molecules without the need for vegetation. While such may be theoretically possible the development of synthetic routes for this which will do better than the natural means that nature has developed through millions of years of evolution will be extremely difficult. It is not likely to happen soon, if at all.

In any case, it is essential that we retain as much of the growing biomass as possible, since its role as a “CO_2 sink” is invaluable. It would be folly, for example, to clear cut forests to plant crops that may be harvested unsustainably for use as feedstock for biofuel facilities or to produce vegetable oils for conversion to biodiesel.

Gasification Of Coal

Another approach to dealing with coal is gasification. Coal can react with steam to yield carbon monoxide and hydrogen. In doing so, the gases may be more readily cleaned and then further reacted to produce hydrocarbons serving as :”synthetic oil” or other useful products. However, the use of these will still convert the carbon in the coal to CO_2 that would add to that necessary to produce the steam. The net result is that this approach would not serve to reduce CO_2 evolution. On the plus side, underground gasification in coal seams is possible with the advantage that it avoids problems involved with coal mining and transportation.

What About Oil?

Some power plants have shifted from coal to oil, but costs have motivated some of them to return to coal. Oil is becoming increasingly scarce and its use in power plants competes with its use for mobile fuel and home heating for which coal is not suitable or convenient. As we approach and possibly pass the period of “peak oil”, costs are likely to become even less competitive.

The Natural Gas Alternative

The other alternative is natural gas which has the advantage of producing less CO_2 per unit of power than coal. Several power plants (such as that at the University of Massachusetts) have shifted from coal to gas, appreciably improving their “carbon footprint”. This shift is recommended, and where possible, new plants should be fueled with natural gas rather than coal. However, such will place increasing demands on the supply of natural gas. While the supply is known to be greater than that of oil, many feel that we shall eventually reach "peak gas", albeit at a later time than that for "peak oil". Recent discoveries and application of newer technologies suggest that natural gas supplies may be greater than previously thought, but it should be realized that these are finite, and one must plan for the time when this resource will also become scarce

Some advocates of natural gas use, such as T, Boone Pickens, have suggested fueling cars with such in that it coverts the chemical energy in the fuel into mechanical energy with greater efficiency than does gasoline or diesel fuel. However, use in private cars leads to the need to develop the infrastructure of fueling stations and of means for compactly storing the gas in cars. It may be more appropriate to promote its use for buses and trucks. In any case, such use places additional demands on its supply.

Thus, use of natural gas as fuel will serve as a temporary solution, but sooner or later, alternatives must be found. Improvement of the efficiency of power plants, as will be discussed, is certainly desirable.

It appears that it may be difficult to satisfy current and prospective energy demands using fossil fuels without causing environmental problems. What might be done? Two approaches are:

1. Reduce energy use through conservation.
2. Develop non-fossil fuel energy sources.

Conservation

Approach (1) is of high priority in that it can be done quickly without the need for much new technology. America is an energy hog, and uses about twice as much energy per capita as most European countries and even much more than much of Asia and the third world. Changes in life style are possible without much sacrifice of the comfort of life and cost. Some are:

1. More use of public transportation. The U.S. is much more dependent on private cars than most of the world. Car pooling arrangements could reduce their use.
2. Improvement of energy efficiency of private vehicles. Car manufacturers have promoted the use of large and powerful cars with rather energy inefficient engines. They have been driven to change because of competition from foreign manufacturers offering more efficient ones. Electrically powered or hybrid cars derive all or part of their energy from power plants which are more energy efficient than gasoline or diesel engines.
3. Encouragement of walking and bicycle use as is done in many foreign countries. Provide bike paths and means for carrying bicycles on buses and trains and storing them at terminals.
4. Changes are possible in housing. “Macmansions” are more prevalent in the U.S. than elsewhere and are inefficient users of energy. Also, with changes in the economy, they are becoming less affordable. Comfortable cooperative and multifamily dwellings might be adopted.
5. Improve energy efficiency of houses. Site them to benefit from sunlight, have better insulation, and multipane windows with coated glass. The choice of color of paint and use of rooftop energy gathering devices can help.
6. Improve the efficiency of lighting and of utilities is desirable. Compact fluorescent lamps and LEDs are much more efficient than incandescents. Newer refrigerators, washers, dryers, and air conditioners are available having much greater efficiency.
7. Change zoning laws to allow more energy efficient practices. Drying clothes using clotheslines, growing vegetables in gardens, and keeping small animals like chickens is frequently restricted. Laws for these should be re-examined.
8. Changes in community planning will help. Resort less on mall-centered shopping and provide these and recreation and cultural facilities closer to housing, minimizing the need to travel.
9. Utilize electronic communication more so as to minimize need to travel. Many business functions can be localized removing

the need to travel to city centers to work. Techniques like videoconferencing may be used to decrease the need to travel to meetings.

10. Generate power in a more energy efficient way as will be discussed in the following section.

Through these and other means, I would guess we could cut per capita energy use by half, appreciable affecting the energy supply and climate problems.

Efficiency Of Power Generation

Efficient power generation has been mentioned in (10). Much of our present power comes from large facilities using fossil fuels. Electric power generation from fuel must obey the laws of thermodynamics, and the Second Law tells us that there is a theoretical limit to the fraction of the chemical energy in fuel that may be concerted into electrical (or mechanical) energy. This fraction depends upon the operating temperature of the generating device and is generally high at higher temperature. For most power plants, it is of the order of 25 - 50%. The remainder of the energy is discharged as heat. For the plant to be energy efficient, this heat energy should be used.

Cogeneration

Such use is accomplished with cogeneration. With this, the discharged heat is used for other purposes like heating buildings or carrying out industrial processes. For example, in the new power plant at the University of Massachusetts in Amherst, the conversion from coal to natural gas and the use of cogeneration has resulted in an increase in efficiency to about 80%. In this case, the discharged heat is used for heating and air conditioning university buildings. Other possibilities are to use the heat for public buildings, schools or facilities like sewage treatment plants.

It is apparent that for cogeneration to work, there must be a means for delivering the heat to the user. For an isolated power plant, this is difficult, although means for piping steam or hot liquids have been developed, It is facilitated in regions of high population density where the producers and users are close together. This, in cities, such as New York, heat is distributed via steam tunnels without too much loss of energy.

Centralized *vs*. Localized Power Generation

It follows that it may be better to have close-by power plants, favoring localized smaller facilities rather than isolated large ones, An advantage is also that these provide more local control and local job opportunities, and the distance over which the electrical power is sent is less, lowering losses in transmission lines. The integration of operation of several smaller plants may be more readily accomplished through computer communication and use of the grid.

Proponents of larger biopower plants contend that while they may be more isolated, there offering of cogeneration produced energy may attract industrial users to locate nearby. This may be, but the possibility must be judged realistically.

On the other hand, delivery of fuel to smaller close-by plants may be more difficult and costly, and lead to objectionable congestion. There is a certain "economy of scale" where certain features need not be duplicated in large plants.

The decision of small vs. large depends upon local conditions. In rural areas where population centers are more dispersed, smaller ones may be favored, whereas in metropolitan areas, more restricted land and availability of users for evolved heat may favor the larger ones. With the larger ones, with needs for more fuel, a consideration is whether sources are readily available. Transportation of fuel over large distances adds to the cost.

If a reasonable fraction of power plants not using cogeneration were to convert, this would reduce energy needs and greenhouse gas problems. However, such conversion is costly, and it is a decision by investors whether it is justified by the increase in efficiency of use of the energy in the fuel.

While conservation and more efficient use may reduce power needs by 50% or more, there will still be needs to be met if use of fossil fuel is abandoned. Thus, non-fossil energy sources need be considered.

Renewable Energy - Hydropower

The most used “renewable source” is hydropower, where electricity is generated by turbines driven by falling water from sources at greater heights. It should be realized that this is really driven by the sun which evaporates water, some from lower heights, leading to rain or snowfall, some of which replenishes the water sources at higher altitudes. While much of this hydropower comes from large dam installations such as Grand Coolee and Hoover in the United States, environmental objections have arisen because of their impact on scenery, marine life and irrigation, and their displacement of farmers and others who had occupied land impounded by the stored water, so not many new ones have been considered and some of the older ones have been demolished. Hence, big projects like that in the Three Gorges in China have been controversial. Possible suitable locations for hydroelectric installations are limited, so transmission of electricity from more distant facilities may be necessary. This has the difficulty that our grid for distributing electricity has not been well maintained. We are somewhat dependent on the import of hydropower from other countries such as Canada, where the terrain is more suitable and population density is less. Another problem is that many sources are dependent upon melting glaciers at mountain altitudes for their water supply, and with possible global warming, these may be of decreasing availability.

While hydropower will probably remain a significant source of energy, it does not seem likely that much growth will be seen. In olden days, locally generated hydropower was used to turn water wheels operating mills, but many of these have been abandoned because of the availability of more economical fossil fuel powered generators. As fossil fuel becomes more scarce, perhaps thought should be given to reviving these sources where more efficiency may be possible with small hydropowered electric generators.

Other sources of hydropower are tidal flows and water ripples and efforts are underway to cover power from these. Again, these are possible in limited locations, so it is not thought that their impact will be large.

Wind Power

Wind power is another renewable energy source which is growing, which is again dependent upon the sun which heats air unevenly and leads to density changes causing winds to occur. With availability of alternative fossil fuel driven sources, the use of windmills as a source of power on farms has declined, but growth is seen with new generations of wind turbines which are more efficient. The use of these in suitable locations where winds are sufficiently strong is growing, but this may be limited by the availability of such places where it can be done economically And by those who object because of their concern of their impact on scenic beauty. I believe that with improvement of technology and the increased cost of alternatives, growth will occur which may provide a few percent of needs.

Solar Power

The direct capture of energy from the sun can be done through solar heating and through use of photovoltaics. Passive solar heating to provide heat for buildings and hot water may be accomplished by choice of suitable locations of buildings and use of rooftop absorption devices to capture the heat. Photovoltaics convert sunlight directly to electricity, and while there use is growing at a significant rate, it is limited by the cost of solar cells having good efficiency. The technology is increasing and with increasing production, the cost is likely to drop. The breakeven point will come when the cost savings over an acceptable period of time will balance the cost of capital investment. The capacity to manufacture photovoltaics in the U.S. is currently limited and we have been dependent upon imports. Also, current designs require use of increasingly scarce materials such as silicon. Manufacture in the U.S. should be encouraged along with the development of siliicon substitutes such as organic photovoltaics.

In the case of both solar and wind, the electricity supply is intermittent and it only comes when the sun is shining or the wind is blowing. Thus a back-up is needed for other times. Batteries are a possibility, but the technology is lacking now but is likely to improve. A better opportunity is to be connected to the grid so that electricity may be imported from utilities when needed. It becomes increasingly possible to have the “meter reverse” and be able to sell electricity back to the utilities when the sun or wind generate excess electricity. Laws are changing such that the utility pays back the user at about the same cost as it charges them. These make these more attractive.

Pumped storage has been employed efforts using ultracapacitors are under study.

It seems likely that rapid technological advances will lead in the future developments like roof shingles that serve as solar cells. As these become more economically competitive, these may contribute significantly to energy resources.

Geothermal

Geothermal energy is another renewable source of energy. There are regions of the earth, in the U.S. mostly in western states, where heated areas are close enough to the earth’s surface to warrant recovering the energy. While such places are limited, it is possible to import heat from cooler regions using a device known as a “heat pump”. Heat normally flows from a hot region to a cold, but in may be “pumped” to flow in the reverse direction using a device the is like a refrigerator, where energy is “pumped: from the cold refrigerator into the warmer room. It requires energy to do this, as is supplied, for example, to the motor of the refrigerator. However the amount of energy required is less than the amount of energy moved, so it is a way of having a net energy supply that is, in part, renewable. It works best in climates which are not too cold, but it is even successfully used in regions close to Amherst.

What Else Is Needed?

All in all, these sources of renewable energy can make an important contribution that will become more attractive as technology improves and fossil fuel becomes more expensive. It is a “wild guess” about how much this will grow in the next decade, but my estimate is that the contribution may be about 30% of present energy use. If conservation brings energy consumption down to about 50%, this leaves a balance of about 20% that must come from other sources, Nuclear may play a role but the safety and public acceptability are questioned. It seems that the remaining possibilities are fossil fuels and biofuels.

Fossil Fuel vs Biofuel

The choice between bio and fossil depends on several factors:

1. Will means for safely and economically disposing of the CO2 arising from fossil fuel burning be found?
2. Will it be economical to use biofuels with sustaiable harvesting so that they are really carbon neutral?

These questions remain to be answered, but they must be in order to make a sensible choice. I believe both approaches should be tried and intensive research should be performed to provide information to facilitate the decision.

Biochar

Another approach, related to the use of biofuels, might be significant and may represent an actual “carbon negative” approach. This involves use of biochar, a charcoal-like material formed by heating biomass with limited air. The process is called *pyrolysis* and should be distinguished from *combustion* or burning where the biomass combines with oxygen to produce CO_2. While it takes some heating to start the pyrolysis, evolving some CO_2, volatile organic vapors are evolved which are combustable and can be burned to provide heat to continue the pyrolysis. The net CO_2 evolution in pyrolysis is considerably less than that arising from combustion, so it is easier to compensate for it with the CO_2 absorbed in the photosynthesis to produce the biomass. There is actually some excess heat which may be recovered and used, but the amount is less than that which would be obtained by burning the biomass. However this disadvantage is believed to be more than offset by the benefits derived from the biochar which is obtained.

Agricultural Benefits

The biochar may serve as an agricultural additive and may be blended with compost and fertilizer and added to soil where iot is believe to enhance agricultural growth. It is believed to remain stable in the soil for long periods of time, centuries or more, so its carbon, coming from the CO_2 which is absorbed from the air during the photosynthesis of the biomass. Hence the net result is that its use reduces the CO_2 content of the atmosphere so that it is “carbon negative”. It may be thought of *as coal mining in reverse* where CO_2 is removed from the atmosphere and its carbon is retained in the soil in an inert form for long times.

There are other advantages to biochar. When used, less fertilizer is needed decreasing the energy required to make it. Also, the fertilizer is bound to its surface, so less of it runs off to rivers and streams where it pollutes. There is believed to be a decrease in the liberation of greenhouse gas producing NOX gases. Also, soil that has been depleted of carbon due to extensive agriculture gets restored. All of this more than compensates for the lower energy release obtained with pyrolysis rather than burning the biomass.

Economics of Biochar Use

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Experiments are being conducted concerning the economics of biochar use on farms. The instituting of cap and trade or a carbon tax would help with the economics of its use as it would make those procedures which liberate CO_2 more costly. An additional advantage would ensue if compensation was made for the value of biochar in reducing atmospheric CO_2 and for its agricultural value. Current legislation is more oriented toward penalizing CO_2 producers, but a revision seems sensible.

Current small scale efforts on farms involve the burning of the liberated vapors during pyrolysis to serve as fuel for its continuation. However, larger scale operations would make it worthwhile to recover these vapors and use them to make salable products. One of these products is known as bio-oil which has the potential of being converted into a mobile fuel or oil that could serve as a replacement for gasoline, diesel oil, and heating oil. The possibility of combined production of biochar and bio-oil is being explored. It successful, this could appreciable add to the economic viability.

Some environmentalists believe that the biochar approach has high probability of success, but I believe it may be wise to stat small to see before going “big time”

The Economics

While some of these approaches may not be competitive with fossil sources at present, they will become increasingly so as technology improves, volume of production leads to cost lowering, and fossil fuel becomes more expensive. It should be realized that fossil fuel users are now getting a “free ride” in that they are not paying for the environmental damage occurring because of their use. This should be considered in formulating future legislation.

In any case, while use may be more costly now, not taking action will be more costly in the future when the need for action to deal with the environmental impact is more realized. Failure to act may necessitate changes in lifestyle and economy that may negatively impact the economy. Any current investment may be compensated by future savings

Conclusions

In conclusion, I believe a combination of approaches is necessary to deal with the energy shortage and climate problem. It has been said that *there is no silver bullet!.* I do not feel that biofuel can solve the problems alone, but it has an important role to play and its use should be explored. It is essential that it be produced using sustainable techniques, but with these, it has the capability of adding to the renewable resources for energy with at least as much importance as the other approaches being considered.